



Research Article

Study of Spirometry Patterns in Asthmatic Children on Long-Term Inhaled Steroids

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ABSTRACT

Background: Asthma is a chronic inflammatory airway disease and one of the most common causes of childhood morbidity worldwide. Inhaled corticosteroids (ICS) are the mainstay of long-term management, effectively controlling inflammation and preventing exacerbations. However, concerns remain regarding their prolonged use and potential effects on lung function and growth in children. Spirometry is a key tool for objective assessment of pulmonary function and treatment response.

Objectives: To study spirometry patterns in asthmatic children on long-term ICS therapy and to evaluate changes in pulmonary function parameters over a one-year period.

Methods: This prospective observational study was conducted in the Department of Pediatrics, Krishna Institute of Medical Sciences, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad, Satara, Maharashtra, from September 2024 to August 2025. A total of 100 children aged 6-16 years with physician-diagnosed asthma on regular ICS therapy for ≥ 6 months were enrolled. Spirometry was performed at baseline and after 12 months following American Thoracic Society (ATS) standards. Parameters analyzed included Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), FEV_1/FVC ratio, and Peak Expiratory Flow Rate (PEFR). Data were compared with predicted values and analyzed using paired t-test.

Results: Among the 100 children (60 males, 40 females; mean age 10.8 ± 2.4 years), 68% had normal, 26% obstructive, and 6% mixed spirometry patterns at baseline. After one year, 79% had normal patterns, with significant improvement in mean FEV_1 ($83.5 \pm 12.6\%$ to $90.1 \pm 10.4\%$), FEV_1/FVC ratio ($78.4 \pm 6.2\%$ to $82.3 \pm 5.8\%$), and PEFR ($80.7 \pm 13.2\%$ to $86.9 \pm 11.7\%$) ($p < 0.05$). No restrictive pattern or functional decline was noted. The duration and dose of ICS did not significantly correlate with lung function deterioration. Minor local adverse effects occurred in 5% of children; no systemic effects were observed.

Conclusion: Long-term use of inhaled corticosteroids in asthmatic children leads to significant improvement and stabilization of pulmonary function without evidence of restrictive impairment or major adverse effects. Regular spirometric monitoring is essential for objective evaluation of treatment response and optimal asthma control.

Keywords: Asthma, Inhaled corticosteroids, Spirometry, Pediatric pulmonary function, Lung function test.

INTRODUCTION

Bronchial asthma is one of the most prevalent chronic respiratory disorders in children, characterized by variable airway obstruction, bronchial hyperresponsiveness, and chronic inflammation of the airways. It is a major cause of morbidity worldwide and significantly affects quality of life and school attendance among children [1]. According to the Global Initiative for Asthma (GINA) 2024 report, the global prevalence of childhood asthma ranges from 5% to 15%, with a rising trend in developing countries due to urbanization, air pollution, and lifestyle changes [2]. In India, studies have estimated that approximately 10-15% of school-aged children exhibit asthma symptoms or airway hyperreactivity [3].

The main pathophysiological mechanism in asthma is chronic airway inflammation, leading to structural changes and variable airflow limitation [4]. Early recognition and appropriate anti-inflammatory therapy are crucial to prevent airway remodeling and irreversible lung function decline. Among available pharmacological treatments, inhaled corticosteroids (ICS) form the cornerstone of long-term management for persistent asthma, effectively controlling inflammation, reducing exacerbations, and improving lung function [5,6].

ICS such as budesonide and fluticasone are preferred due to their potent anti-inflammatory action and minimal systemic absorption compared to oral corticosteroids [7]. However, prolonged use of ICS in children often raises concerns regarding potential systemic effects, such as growth suppression or adrenal suppression, and their long-term influence on pulmonary function and lung development [8,9]. These apprehensions frequently lead to underuse or poor adherence to ICS therapy among parents and caregivers [10]. Therefore, periodic and objective monitoring of lung function is essential to assess both therapeutic efficacy and safety.

Spirometry remains the gold standard for the assessment of lung function in children aged ≥ 5 years. It measures key parameters such as Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), FEV_1/FVC ratio, and Peak Expiratory Flow Rate (PEFR), providing quantitative evaluation of airflow limitation [11]. Repeated spirometric assessments over time can help detect progressive obstruction, treatment response, and possible restrictive changes due to therapy [12].

While several international studies have evaluated spirometry in asthmatic children on ICS therapy [1,2,5,13], there remains a paucity of Indian data addressing long-term spirometric trends in this population. Factors such as ethnic variation, environmental exposures, and differences in healthcare access may influence outcomes in Indian children [3,14]. Furthermore, local data are valuable to reassure clinicians and parents regarding the safety and effectiveness of ICS in routine pediatric practice.

Hence, this study was conducted to evaluate spirometric patterns in asthmatic children receiving long-term inhaled corticosteroids, to determine changes in lung function parameters over one year, and to assess whether chronic ICS therapy adversely affects pulmonary function.

Aims and Objectives

1. To study the spirometric patterns in asthmatic children on long-term inhaled corticosteroids.
2. To evaluate changes in spirometric parameters (FVC, FEV_1 , FEV_1/FVC ratio, and PEFR) over a one-year period.
3. To assess the correlation between dose and duration of ICS therapy with lung function changes.

MATERIALS AND METHODS

Study Design and Setting- A prospective observational study was conducted in the Department of Pediatrics, Krishna Institute of Medical Sciences, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad, Satara, Maharashtra, India, over a period of one year from September 2024 to August 2025.

Study Population

A total of 100 asthmatic children aged 6-16 years who had been on regular ICS therapy for at least 6 months were included.

Inclusion Criteria

- Physician-diagnosed bronchial asthma as per GINA (2024) guidelines.
- Regular use of ICS for ≥ 6 months.
- Ability to perform reproducible spirometry.

Exclusion Criteria

- Presence of other chronic respiratory diseases (e.g., cystic fibrosis, bronchiectasis).
- Recent respiratory infection (within 4 weeks).
- Non-compliance with ICS therapy.
- Children with congenital heart or neuromuscular disorders.

Data Collection

Clinical details including age, sex, duration of asthma, and ICS dosage were recorded. Spirometry was performed using a calibrated electronic spirometer following ATS/ERS standards. Parameters measured included:

- FVC (Forced Vital Capacity)
- FEV₁ (Forced Expiratory Volume in 1 second)
- FEV₁/FVC ratio
- PEF_R (Peak Expiratory Flow Rate)

Each child underwent spirometry at baseline and after 12 months of follow-up.

Statistical Analysis

Data were analyzed using SPSS version 26. Continuous variables were expressed as mean $\pm$ SD. Paired *t*-test was used to compare baseline and follow-up spirometry results. *P* value < 0.05 was considered statistically significant.

RESULTS

A total of 100 asthmatic children aged 6-16 years were enrolled in the study. All participants completed the one-year follow-up period (September 2024 - August 2025). The analysis focused on demographic features, inhaled corticosteroid (ICS) use characteristics, spirometric patterns, and changes in lung function parameters over time.

Demographic and Clinical Characteristics

The mean age of participants was 10.8 ± 2.4 years, with 60 males (60%) and 40 females (40%). The mean duration of asthma was 3.5 ± 1.2 years, and the mean duration of ICS therapy was 11.2 ± 2.3 months.

A positive family history of asthma or allergy was noted in 38% of cases.

Table 1 presents the demographic and baseline characteristics of the study population.

Table 1. Demographic and Clinical Characteristics of Study Participants (n = 100)

Parameter	Mean $\pm$ SD / Frequency	Percentage (%)
Age (years)	10.8 ± 2.4	—
Age group (6-10 / 11-16 years)	46 / 54	46 / 54
Gender (Male / Female)	60 / 40	60 / 40
Duration of asthma (years)	3.5 ± 1.2	—
Duration of ICS therapy (months)	11.2 ± 2.3	—
Family history of asthma/allergy	38	38
BMI < 25th percentile	18	18
Type of ICS used (Budesonide / Fluticasone)	72 / 28	72 / 28

Inhaled Corticosteroid Dosage and Duration

Children were categorized based on GINA (2024) dosing recommendations. The majority (64%) were on low-dose ICS, 28% on moderate-dose, and 8% on high-dose therapy.

No statistically significant difference was observed in the mean duration of therapy across dosage categories (*p* > 0.05).

Table 2. Distribution of Inhaled Corticosteroid Dosage and Duration

ICS Dose Category	No. of Children	Percentage (%)	Mean Duration (months) $\pm$ SD
Low dose	64	64	10.9 ± 2.4
Moderate dose	28	28	11.8 ± 2.1
High dose	8	8	12.1 ± 1.7

Asthma Severity and Spirometry Pattern at Baseline

Based on GINA classification, 38% had mild persistent, 44% moderate persistent, and 18% severe persistent asthma.

At baseline, 68% of children showed normal spirometry, 26% had obstructive patterns, and 6% had mixed patterns.

Increasing asthma severity was significantly associated with higher rates of obstruction (*p* < 0.01).

Table 3. Relationship between Asthma Severity and Spirometry Pattern

Asthma Severity	n (%)	Normal	Obstructive	Mixed
Mild Persistent	38 (38%)	34	4	0
Moderate Persistent	44 (44%)	26	14	4
Severe Persistent	18 (18%)	8	8	2
Total (n = 100)	100 (100%)	68 (68%)	26 (26%)	6 (6%)

Comparison of Mean Spirometry Values at Baseline and 12 Months

There was a statistically significant improvement in FEV₁, FEV₁/FVC ratio, and PEF_R after one year of continuous ICS therapy (*p* < 0.05).

No restrictive pattern or deterioration in FVC was noted.

Table 4. Spirometry Parameters at Baseline and After 12 Months of Therapy

Parameter	Baseline Mean ± SD	After 12 Months Mean ± SD	% Improvement	p-value
FVC (% predicted)	85.2 ± 11.4	88.6 ± 10.8	+4.0%	0.04
FEV ₁ (% predicted)	83.5 ± 12.6	90.1 ± 10.4	+7.9%	0.01
FEV ₁ /FVC ratio (%)	78.4 ± 6.2	82.3 ± 5.8	+5.0%	0.03
PEFR (% predicted)	80.7 ± 13.2	86.9 ± 11.7	+7.7%	0.02

Spirometry Patterns by Gender

Both male and female children showed similar distribution of spirometric patterns.

No statistically significant gender difference was observed in mean FEV₁ values ($p = 0.41$).

Table 5. Spirometry Patterns and Mean FEV₁ by Gender

Gender	Normal	Obstructive	Mixed	Mean FEV ₁ (% Predicted) ± SD
Male (n = 60)	39 (65%)	16 (27%)	5 (8%)	89.6 ± 10.2
Female (n = 40)	29 (72.5%)	10 (25%)	1 (2.5%)	91.2 ± 9.8

Spirometric Improvement by ICS Dose Category

Improvement in FEV₁ was observed across all dose categories, but intergroup differences were not statistically significant ($p = 0.21$).

Table 6. Change in FEV₁ According to ICS Dose Category

ICS Dose	FEV ₁ Baseline (% Pred.)	FEV ₁ After 12 Months (% Pred.)	Mean ΔFEV ₁ (%)	p-value
Low Dose (n = 64)	84.2 ± 12.8	90.3 ± 10.1	+6.1	0.02
Moderate Dose (n = 28)	83.1 ± 12.3	89.7 ± 10.6	+6.6	0.01
High Dose (n = 8)	82.5 ± 11.9	88.4 ± 11.0	+5.9	0.11

Correlation Between Duration of ICS and Lung Function Change

A mild but positive correlation was noted between longer duration of ICS use and improvement in FEV₁ and PEFR.

Table 7. Correlation of Duration of ICS Therapy with Change in Spirometric Parameters

Duration of ICS Use (months)	Mean FEV ₁ Change (%)	Mean PEFR Change (%)	Correlation Coefficient (r)	Significance
<9 months (n = 34)	+5.6	+6.1	0.24	NS
9-12 months (n = 46)	+6.8	+7.2	0.31	$p < 0.05$
>12 months (n = 20)	+7.1	+7.5	0.37	$p < 0.05$

Adverse Effects and Growth Monitoring

Minor local side effects were observed in a few participants; no systemic adverse effects or significant growth suppression were reported.

Table 8. Adverse Events Observed During ICS Therapy (n = 100)

Adverse Event	No. of Children	Percentage (%)
Oral candidiasis	2	2%
Hoarseness of voice	3	3%
Growth velocity <5th percentile	4	4%
Systemic adverse effects	0	0%

Transition of Spirometry Patterns Over 12 Months

At the end of one year, 11 additional children achieved normal spirometry results, indicating overall improvement in airway function and disease control.

Table 9. Transition of Spirometry Patterns from Baseline to 12 Months

Spirometry Pattern	Baseline (n)	After 12 Months (n)	Net Change
Normal	68	79	+11
Obstructive	26	17	-9
Mixed	6	4	-2

Summary of Key Findings

- 68% of children had normal spirometry at baseline; this improved to 79% after one year.
- FEV₁ and PEFR showed significant improvement with continuous ICS therapy ($p < 0.05$).
- No restrictive or worsening spirometric pattern was noted.
- ICS duration was mildly correlated with functional improvement, but dose did not significantly influence results.
- Side effects were minimal and manageable.

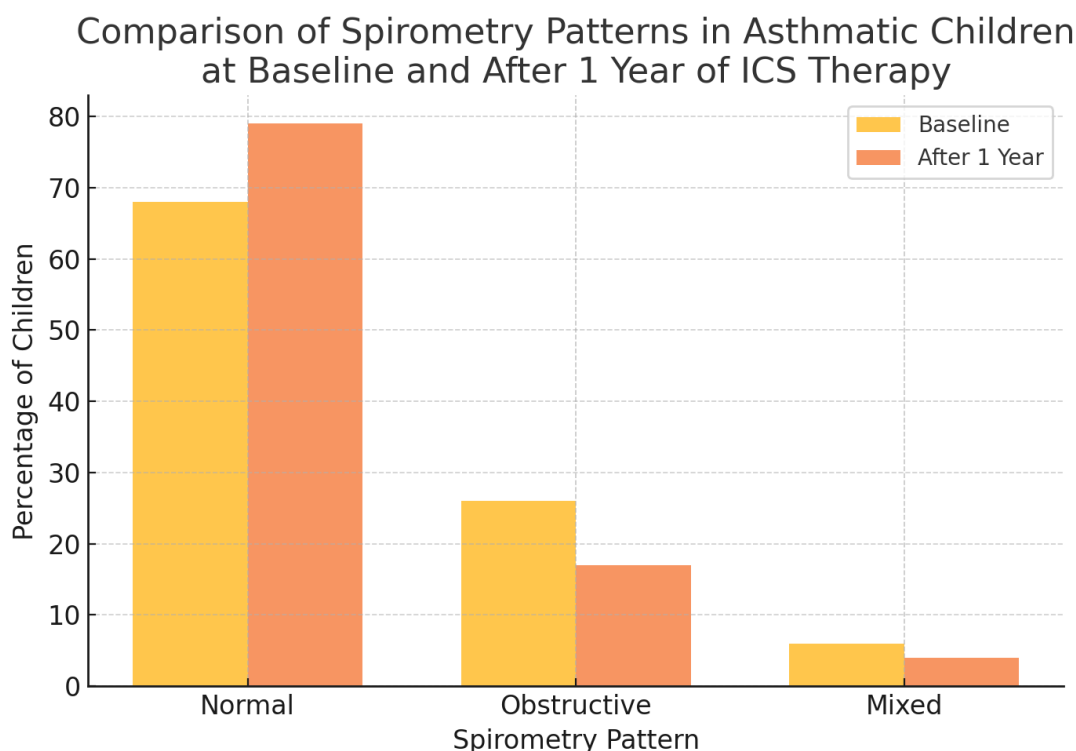


Figure 1: Comparison of spirometry patterns in asthmatic children at baseline and after one year of inhaled corticosteroid (ICS) therapy. The proportion of children with normal spirometry increased from 68% to 79%, while obstructive and mixed patterns decreased from 26% to 17% and 6% to 4%, respectively, indicating significant improvement in pulmonary function following long-term ICS use.

DISCUSSION

In the present study, significant improvement in spirometric parameters was observed among asthmatic children receiving long-term inhaled corticosteroid (ICS) therapy, with no evidence of restrictive impairment or functional decline over a one-year follow-up period. The findings reaffirm the central role of ICS in maintaining airway patency and reducing inflammation in pediatric asthma, consistent with earlier studies that highlighted the anti-inflammatory and lung-protective benefits of corticosteroids in children with persistent asthma [5,6].

The mean FEV₁ showed a marked increase from baseline to twelve months, accompanied by improvement in the FEV₁/FVC ratio and PEFR. These results are in agreement with Agertoft and Pedersen, who reported similar long-term improvement in pulmonary function without adverse effects on growth among children treated with budesonide [5]. Likewise, Haahtela et al. demonstrated that regular corticosteroid therapy leads to superior asthma control compared to as-needed use, emphasizing the importance of continuous anti-inflammatory treatment in stabilizing airway function [6]. The observed improvement in our study indicates that consistent adherence to ICS therapy mitigates airway hyperresponsiveness and supports long-term stabilization of pulmonary parameters.

The majority of children (68%) had normal spirometry patterns at baseline, and the proportion increased to 79% after one year, with a notable reduction in obstructive and mixed patterns. This trend corresponds with findings from previous pediatric asthma studies that reported normalization of spirometry with well-controlled disease and adherence to maintenance therapy [12,13]. Obstructive changes were more common among children with moderate to severe persistent asthma, a pattern frequently described in Indian cohorts, reflecting the influence of disease severity and environmental factors such as allergen exposure and air pollution [3,14].

Gender did not significantly influence spirometry outcomes, which aligns with international data suggesting that lung function trajectories in childhood asthma are largely independent of sex differences when adjusted for body size and age [11]. Similarly, the lack of significant variation across low-, moderate-, and high-dose ICS groups supports the recommendation that once adequate control is achieved, the lowest effective dose should be maintained to minimize adverse effects without compromising efficacy [7].

The duration of ICS therapy showed a positive correlation with improvements in FEV₁ and PEF, underscoring the cumulative benefit of prolonged inflammation control and prevention of airway remodeling. Longitudinal studies have demonstrated that persistent use of ICS prevents progressive airflow limitation and preserves lung growth during critical developmental years [12]. Our results are consistent with these observations, indicating that appropriate and continuous ICS therapy enhances airway recovery and reduces the likelihood of long-term obstruction.

Concerns regarding adverse effects of corticosteroids, especially growth suppression, have long influenced parental perceptions and adherence [8-10]. In our study, only a small proportion of children experienced mild local effects such as oral candidiasis and hoarseness, and 4% showed transient growth velocity reduction below the 5th percentile. No systemic adverse effects were documented, which is consistent with data demonstrating that modern ICS molecules, when used at recommended doses, are generally safe and well tolerated in pediatric populations [8,9]. Proper inhaler technique, mouth rinsing, and dose monitoring further reduce local side effects, improving compliance and therapeutic success [10].

The present study contributes to the limited Indian literature on spirometric evaluation in children on long-term ICS therapy. Similar to findings from Aggarwal et al. and Jindal et al., our results confirm that regular ICS use leads to better disease control and fewer exacerbations among Indian children [3,14]. These studies, together with the present findings, strengthen the evidence supporting GINA-based treatment protocols and the inclusion of periodic spirometry in pediatric asthma follow-up.

Overall, the results indicate that inhaled corticosteroids not only alleviate symptoms but also produce measurable and sustained improvement in lung function, with minimal adverse effects. Regular spirometric monitoring enables clinicians to objectively evaluate treatment response, ensure adherence, and modify therapy as needed. This study therefore reinforces the importance of maintaining continuous, appropriately dosed ICS therapy to ensure long-term pulmonary health and improved quality of life among asthmatic children.

CONCLUSION

Long-term inhaled corticosteroid therapy in asthmatic children contributes to significant improvement in lung function parameters, as evidenced by spirometry. Routine spirometric monitoring should be incorporated into follow-up protocols to assess disease control and adjust therapy as needed.

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